Physics and Political Update

NOνA Collaboration Meeting

Fermilab

2 October 2004

Gary Feldman

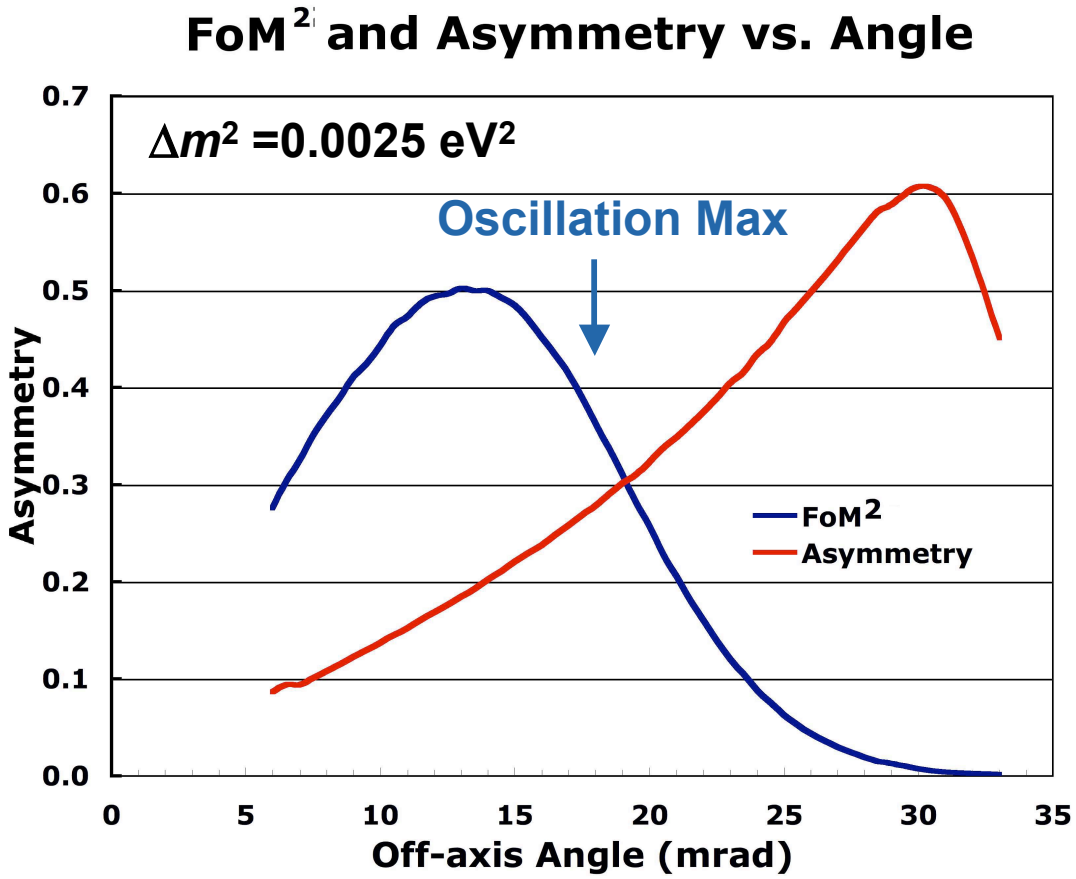
Topics

- Presentation to the PAC Aspen Meeting
- PAC Response
- Visit to DoE
- Outlook

PAC Concerns from the April Meeting

- The PAC seemed to be concerned that
  - NOνA is just a duplication of T2K, and if T2K runs earlier, NOνA could be irrelevant, and that
  - NOνA is being optimized for the near term and will not be the right detector for later use.
- We submitted Appendix D to the June meeting
  - to reorient NOνA toward its unique role in resolving the mass hierarchy,
  - to show that there is a progression of steps that allows the resolution of the mass hierarchy for all values of the CP phase δ and an order of magnitude range of $\sin^2(2\theta_{13})$, and
  - to show that NOνA is optimized for all stages of this progression, even with reasonable uncertainty on the value of Δm^2.

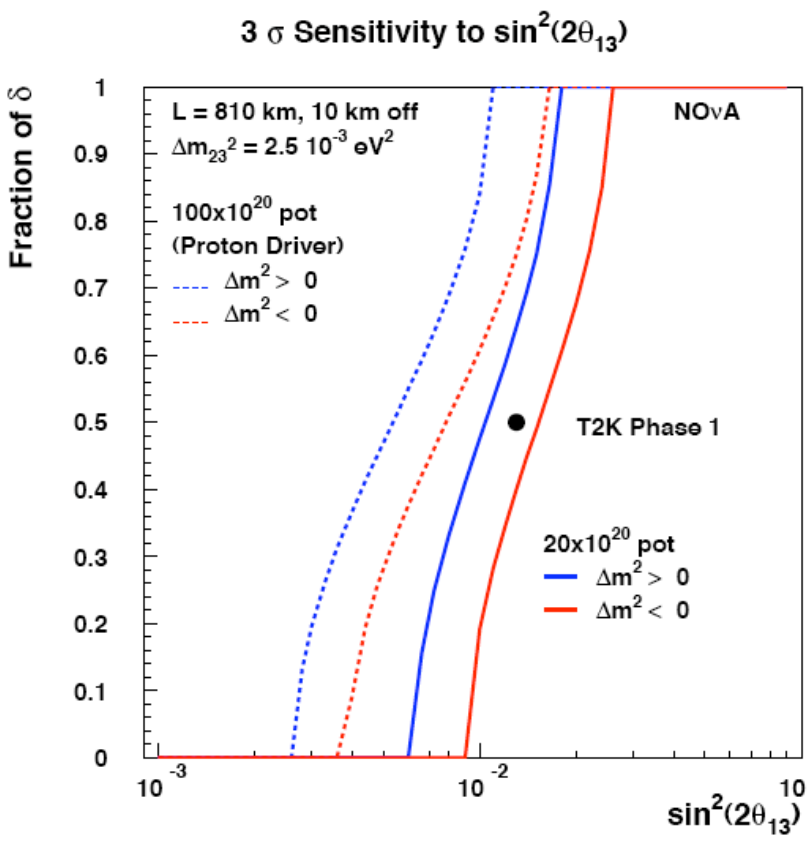
The Optimization Problem

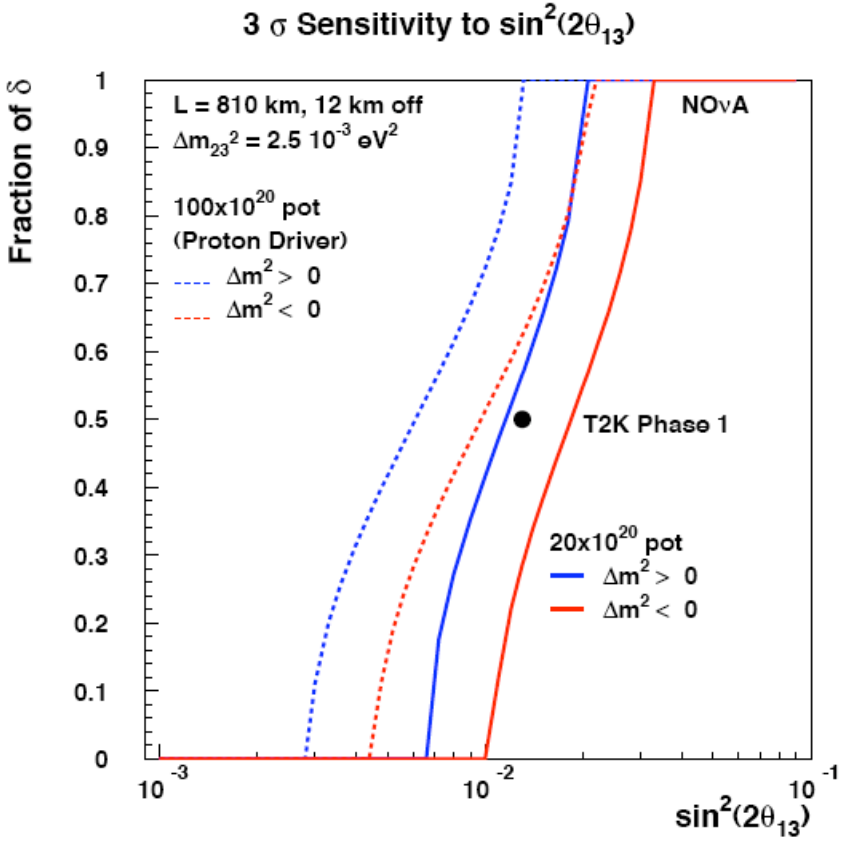


$$\text{FoM} = \frac{\text{signal}}{\sqrt{\text{background}}}$$

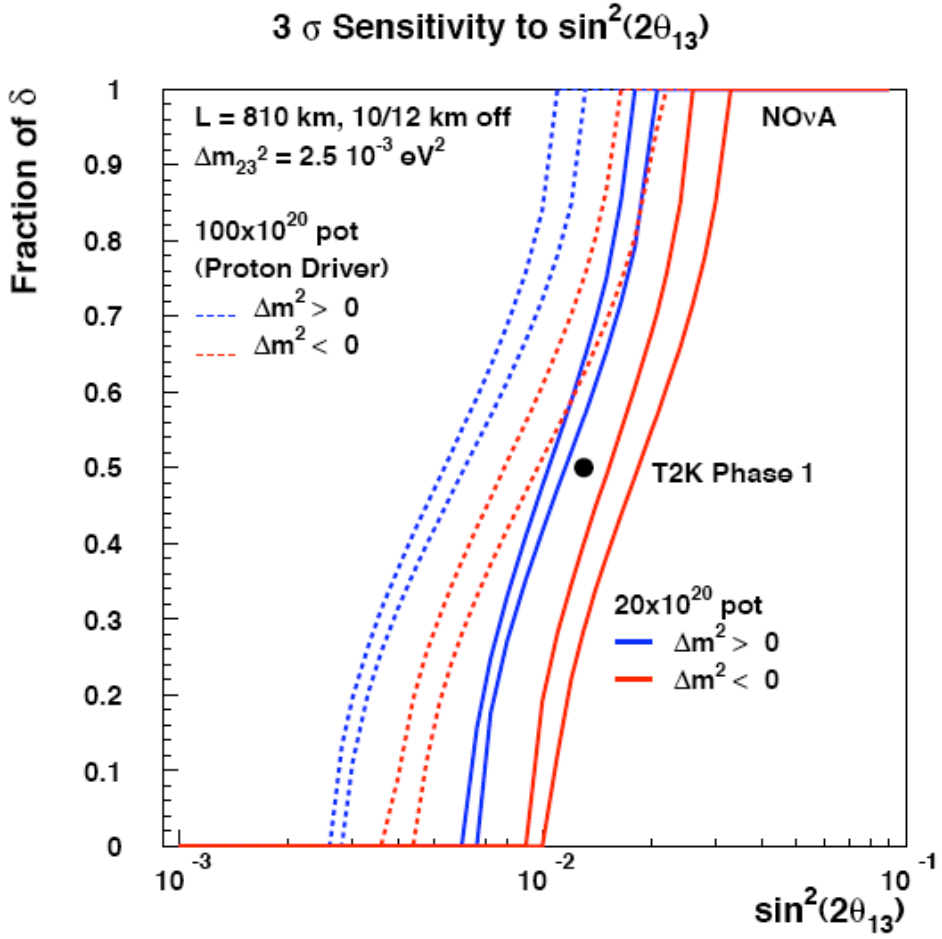
$$\text{Asymmetry} = \left(\frac{\sigma_{\nu} - \sigma_{\bar{\nu}}}{\sigma_{\nu} + \sigma_{\bar{\nu}}} \right)$$

3 σ Discovery Potential for $\nu_\mu \rightarrow \nu_e$

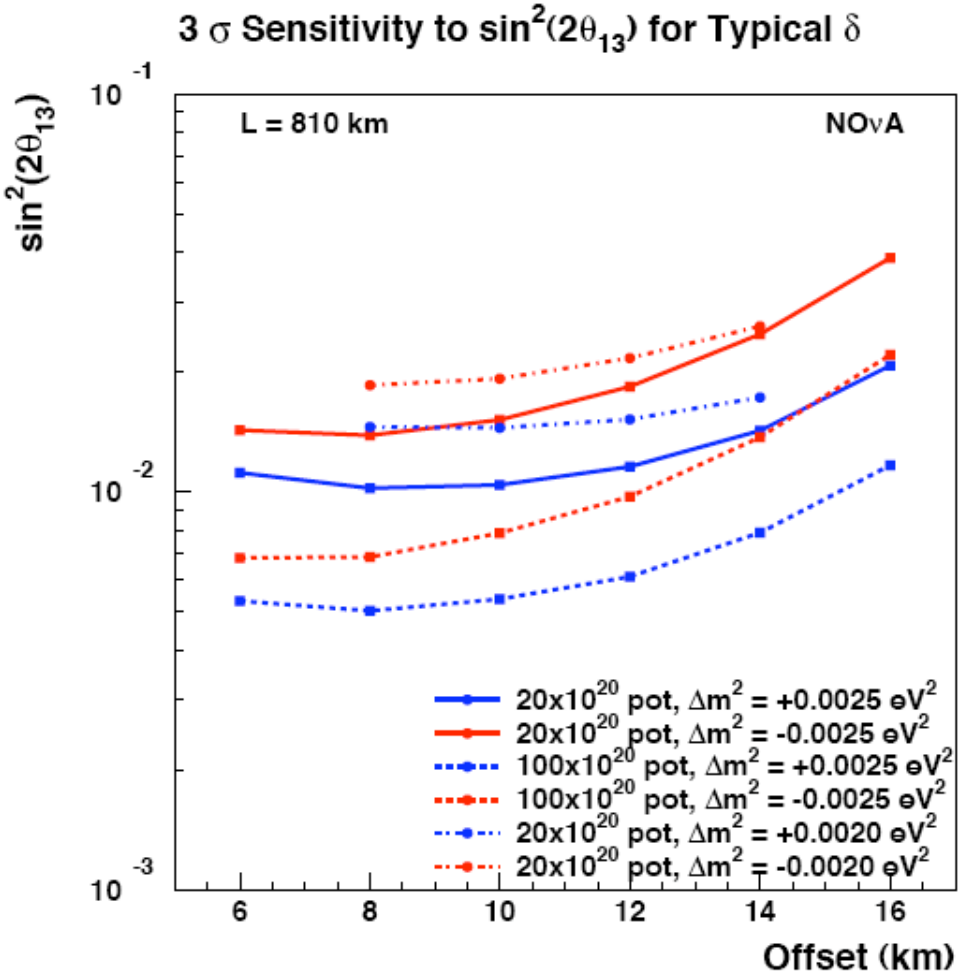




Comparison of 10 and 12 km

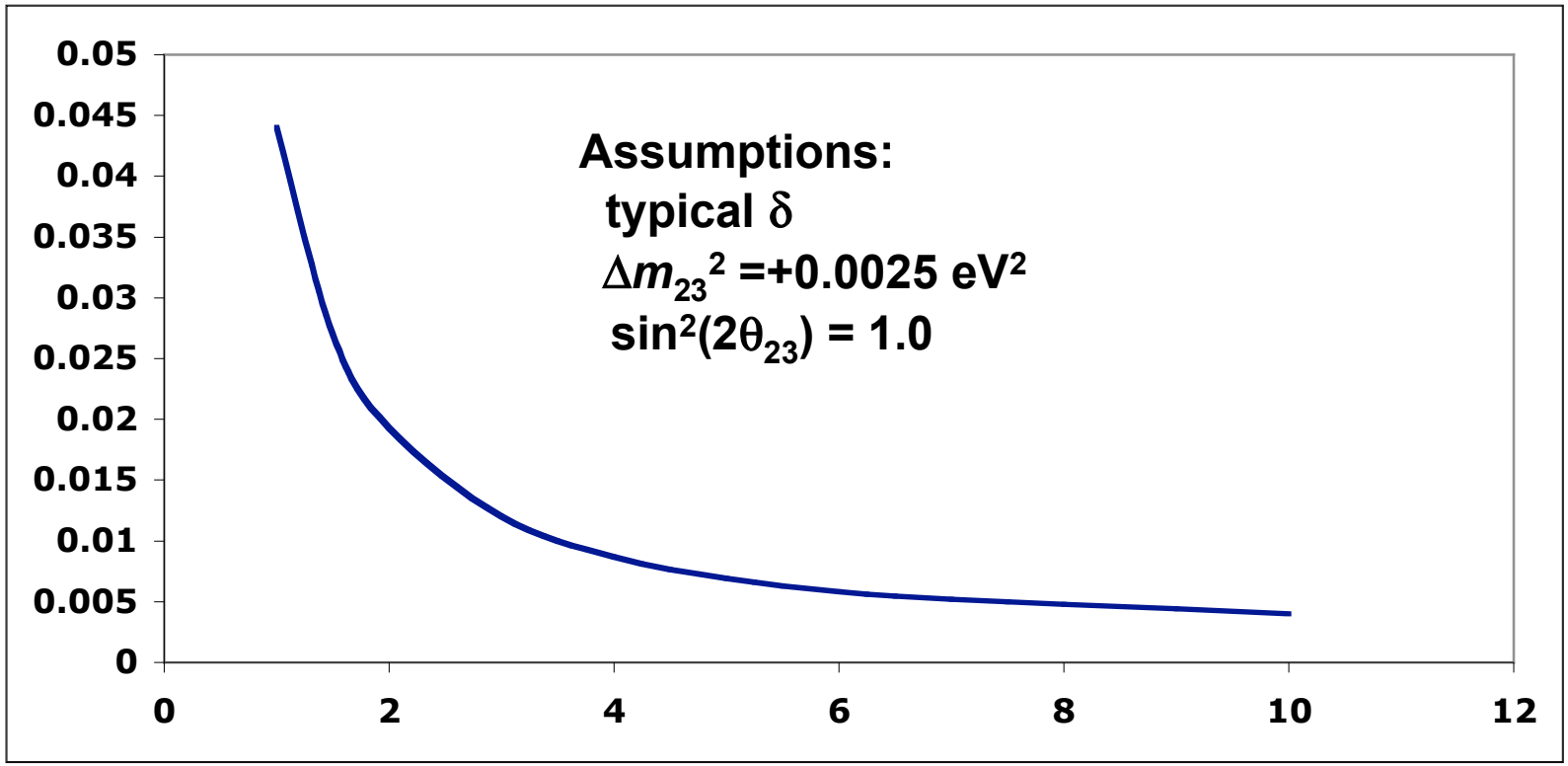


3 σ Discovery Potential for $\nu_\mu \rightarrow \nu_e$ vs. Off-Axis Distance



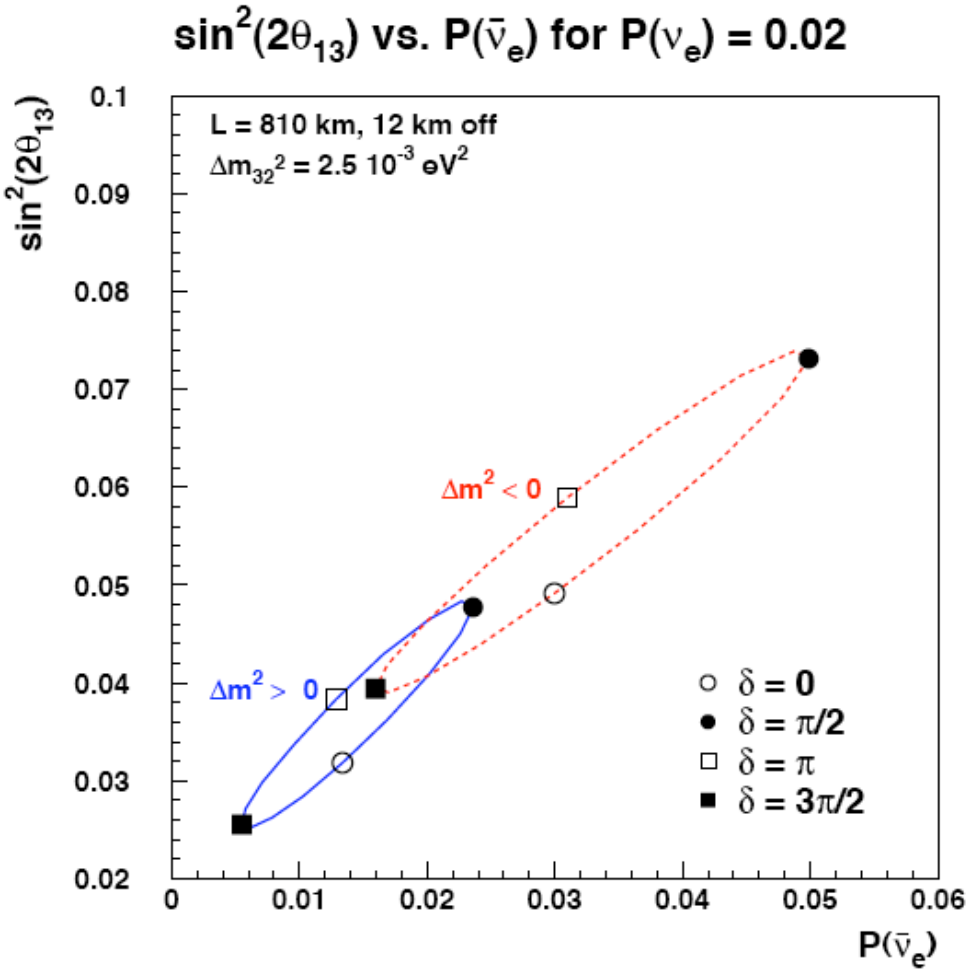
Note: There is a loss of sensitivity for $\Delta m^2 = 0.002$ eV², but not a loss of range, since the CHOOZ limit is correspondingly weaker there.

95% CL on $\sin^2(2\theta_{13})$ vs. years from start of installation

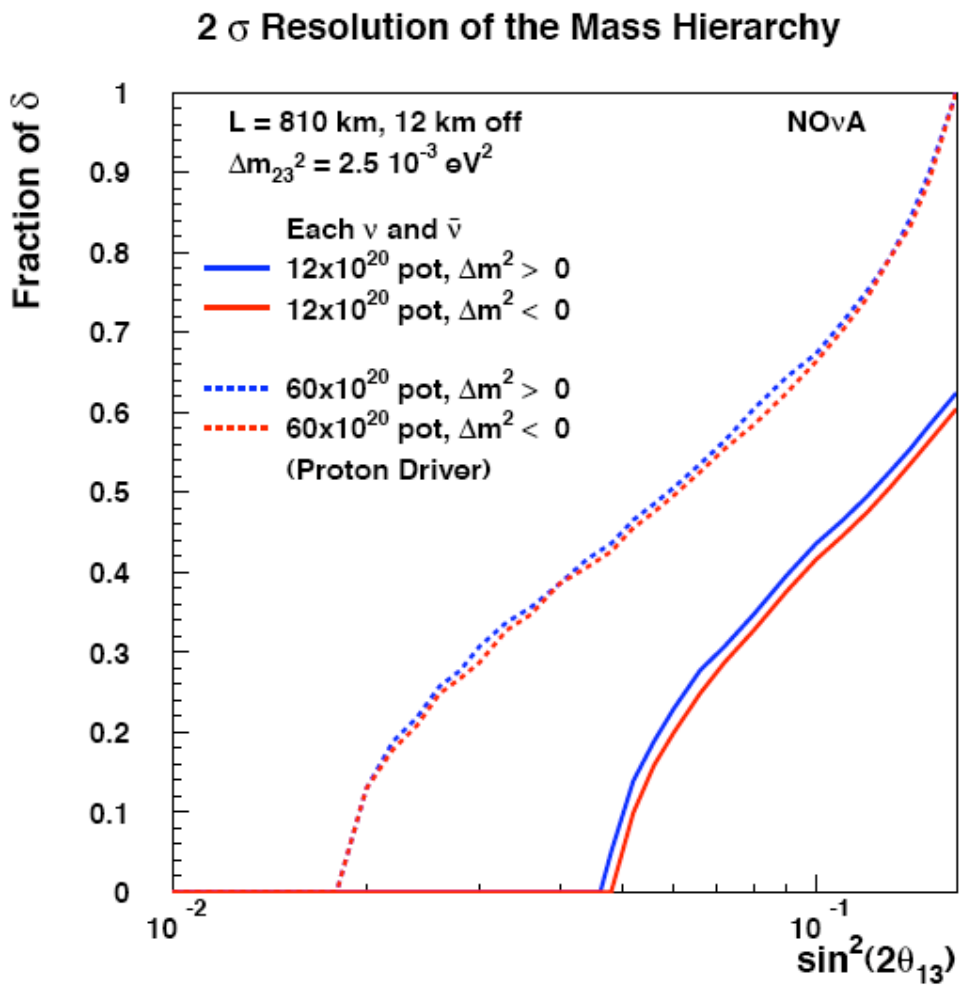


Years from start of installation

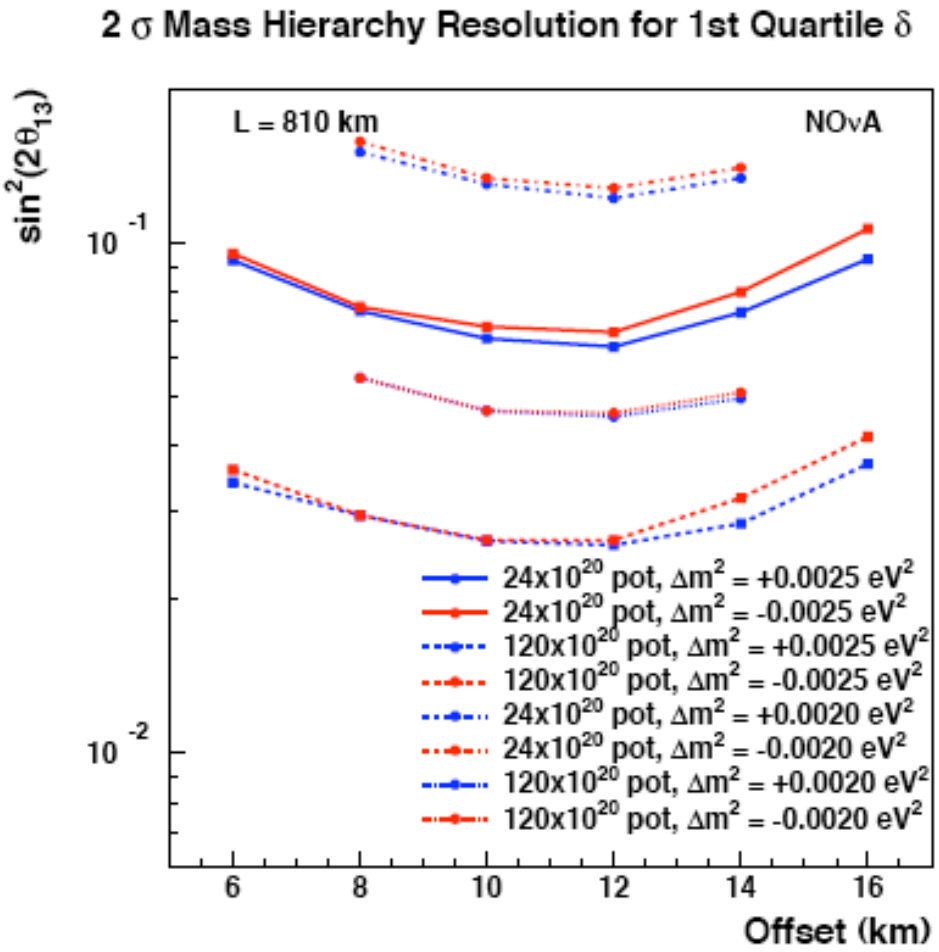
Reminder of the Problem Part 1



95% CL Resolution of the Mass Hierarchy

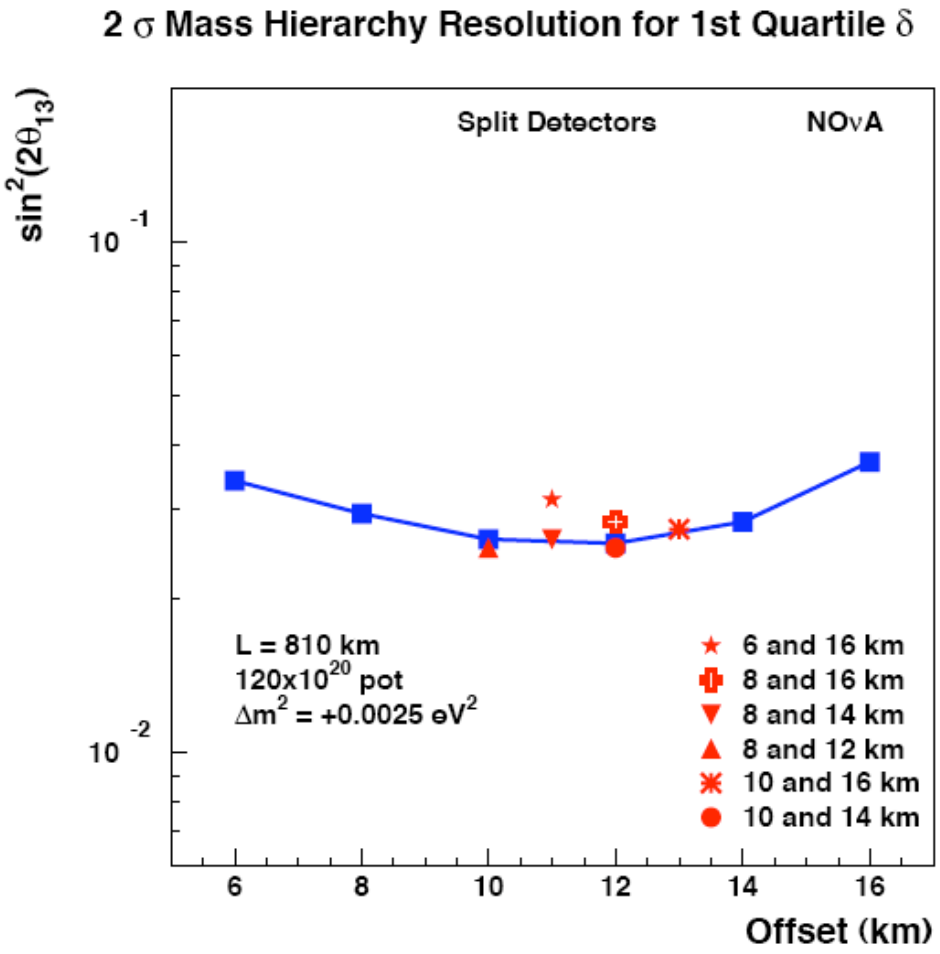


Mass Hierarchy Resolution vs. Off-Axis Distance



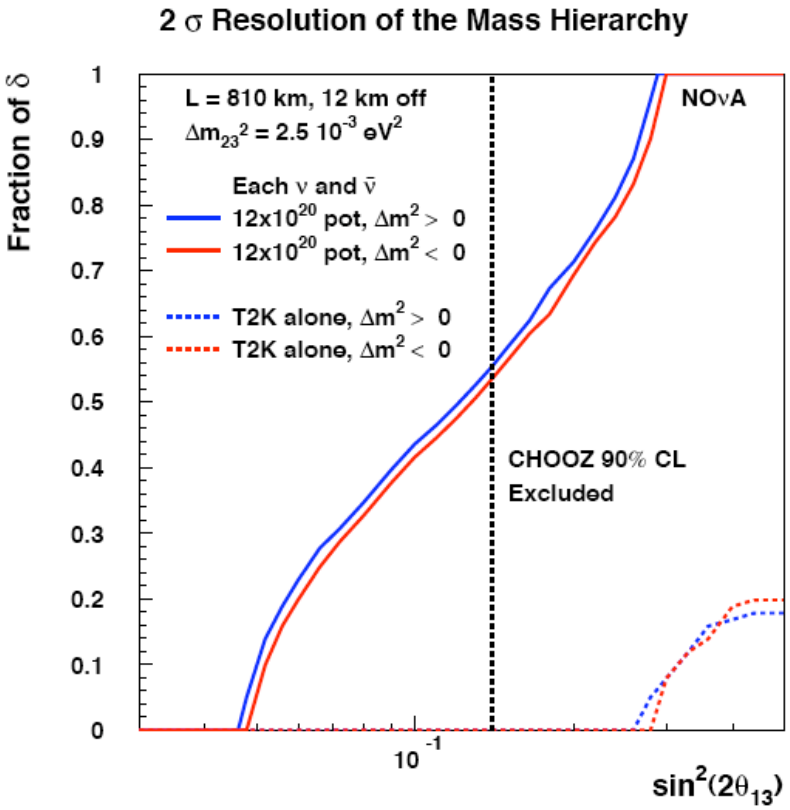
12 km off-axis is best for both $\Delta m^2 = 0.0025$ and $\Delta m^2 = 0.0020$ eV²

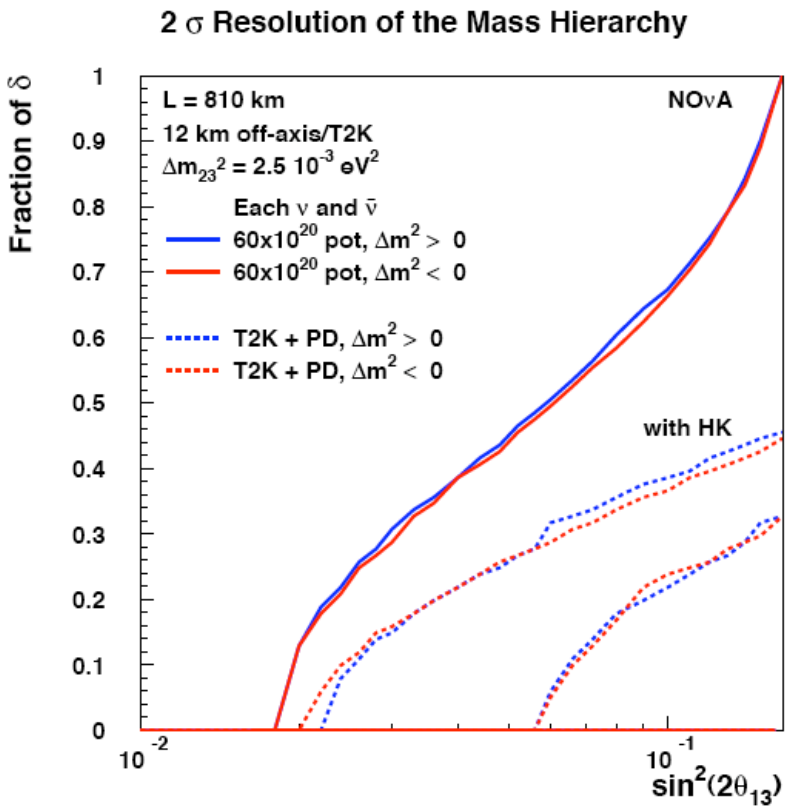
PAC Question: Are two (1/2) Detectors Better than One?



Answer: Yes, but not by enough to overcome the fiducial and infra-structure costs.

NOνA Alone vs. T2K Alone

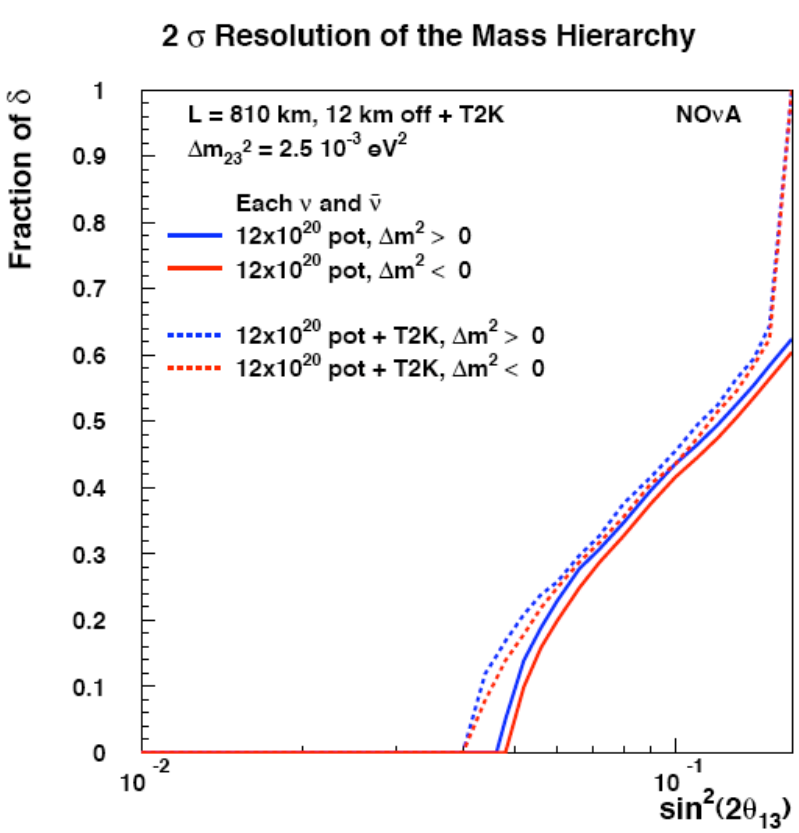


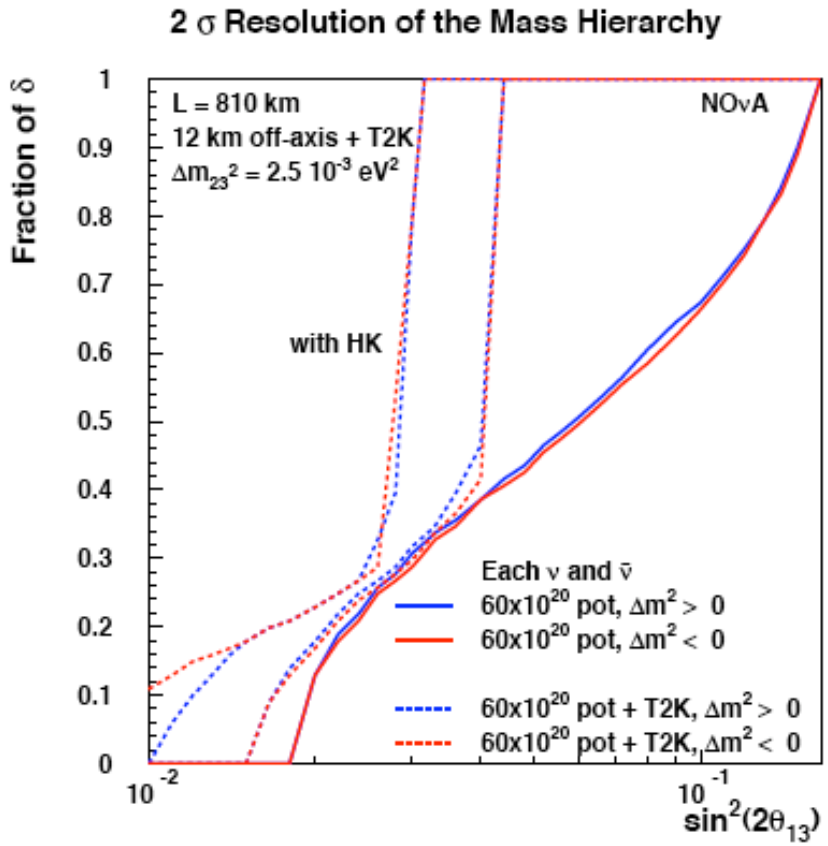


Note change of horizontal scale

Proton Drivers

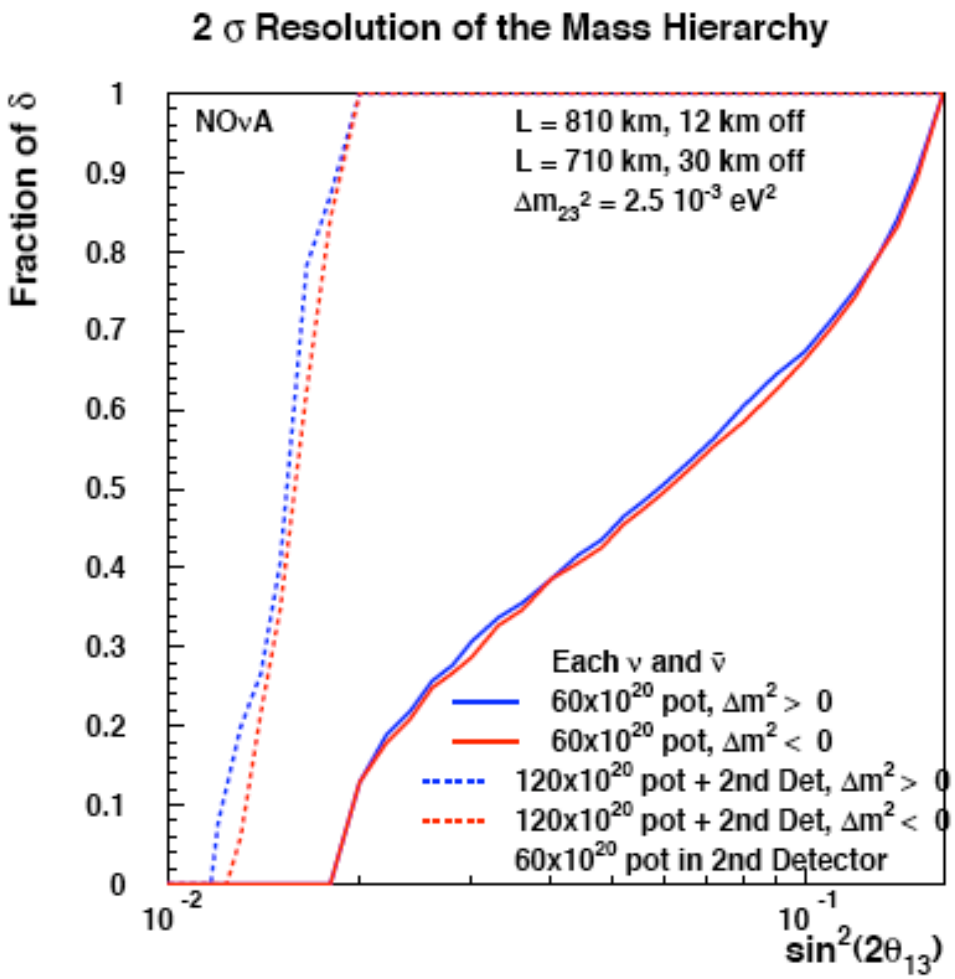
Combination with T2K



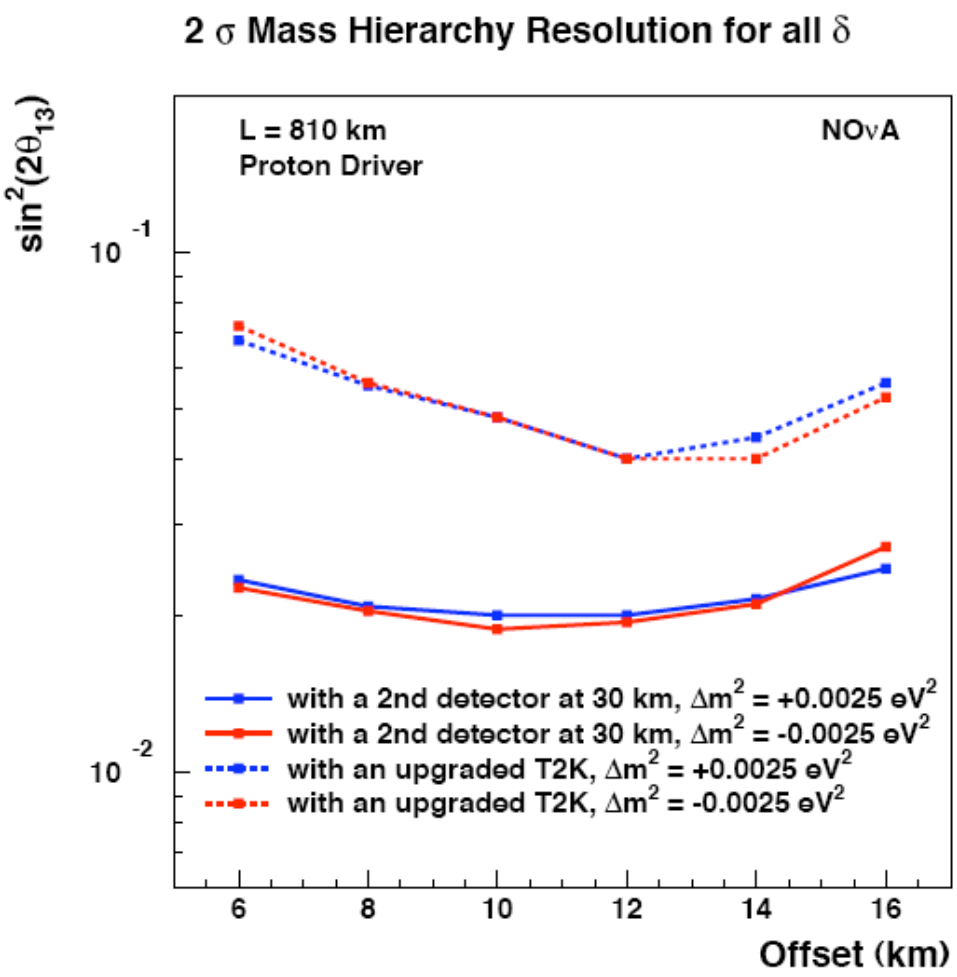


Proton Drivers

Combination with a 2nd OA Detector at the 2nd Maximum

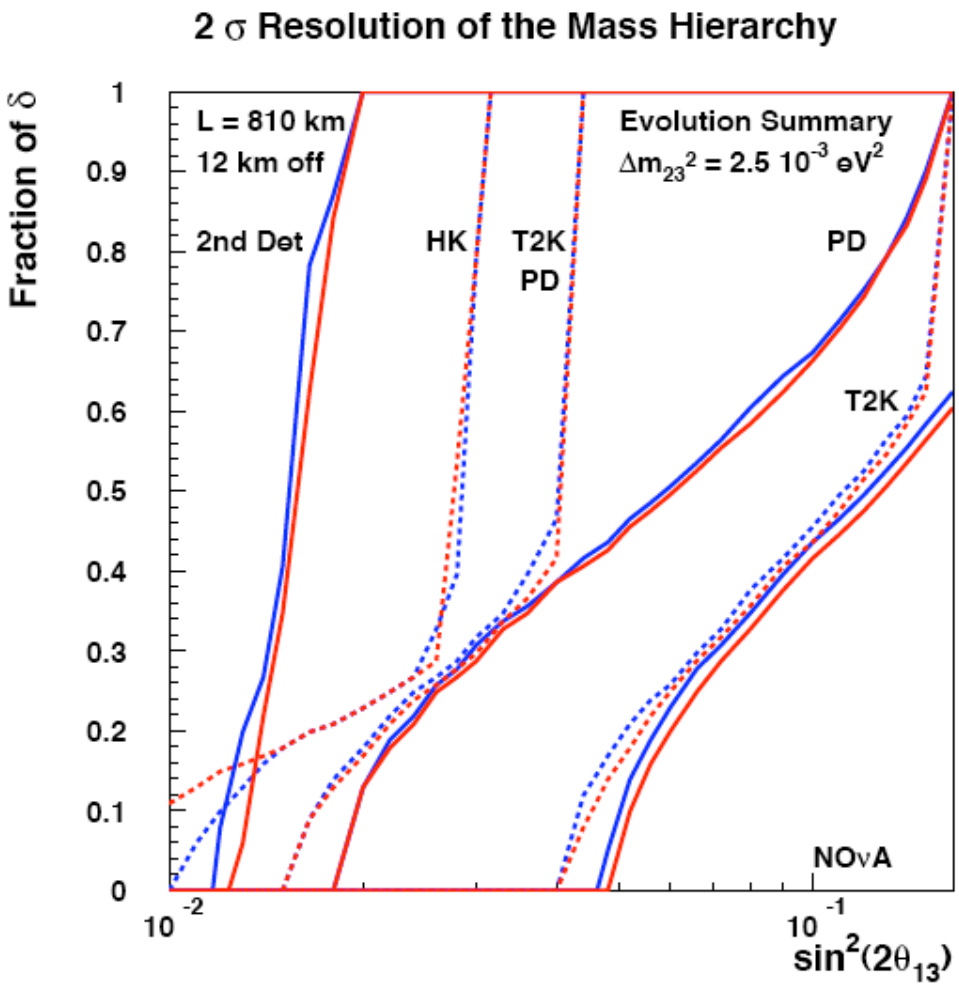


Mass Hierarchy Resolution vs. Off-Axis Distance

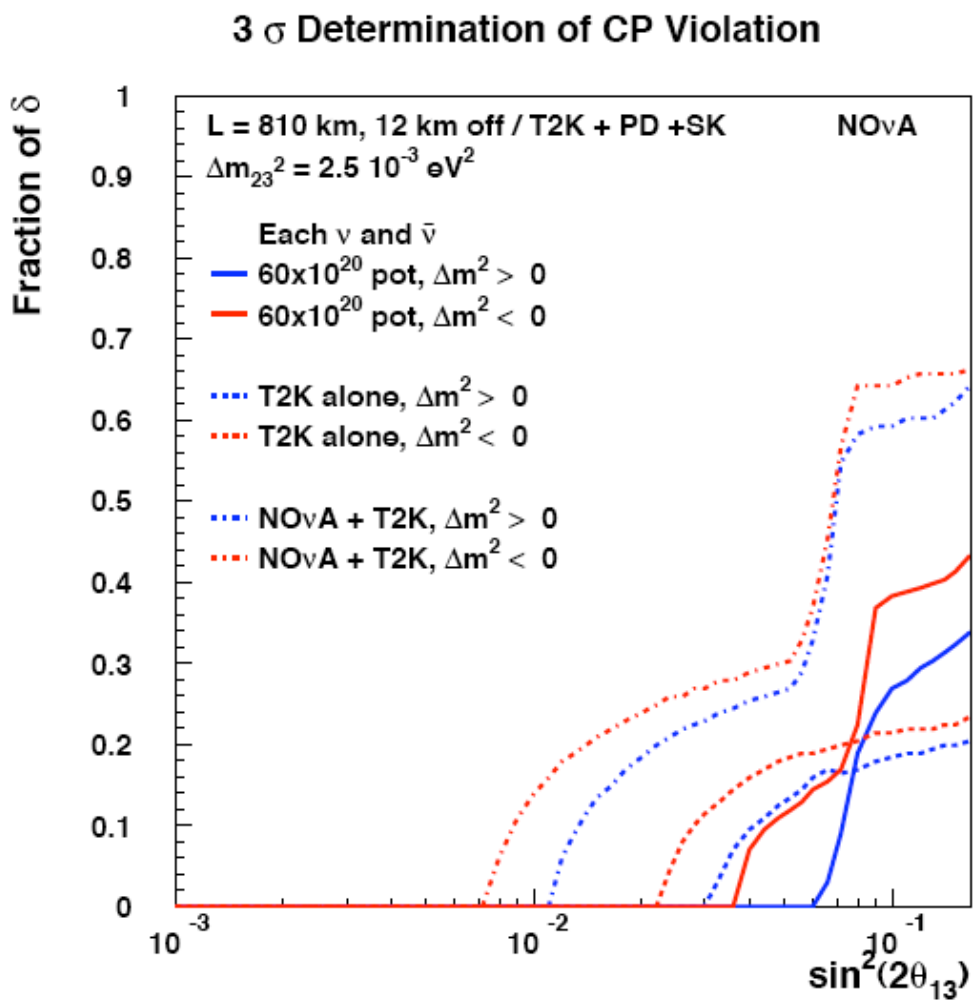


Again, 12 km provides a good optimization.

Mass Hierarchy Resolution Summary



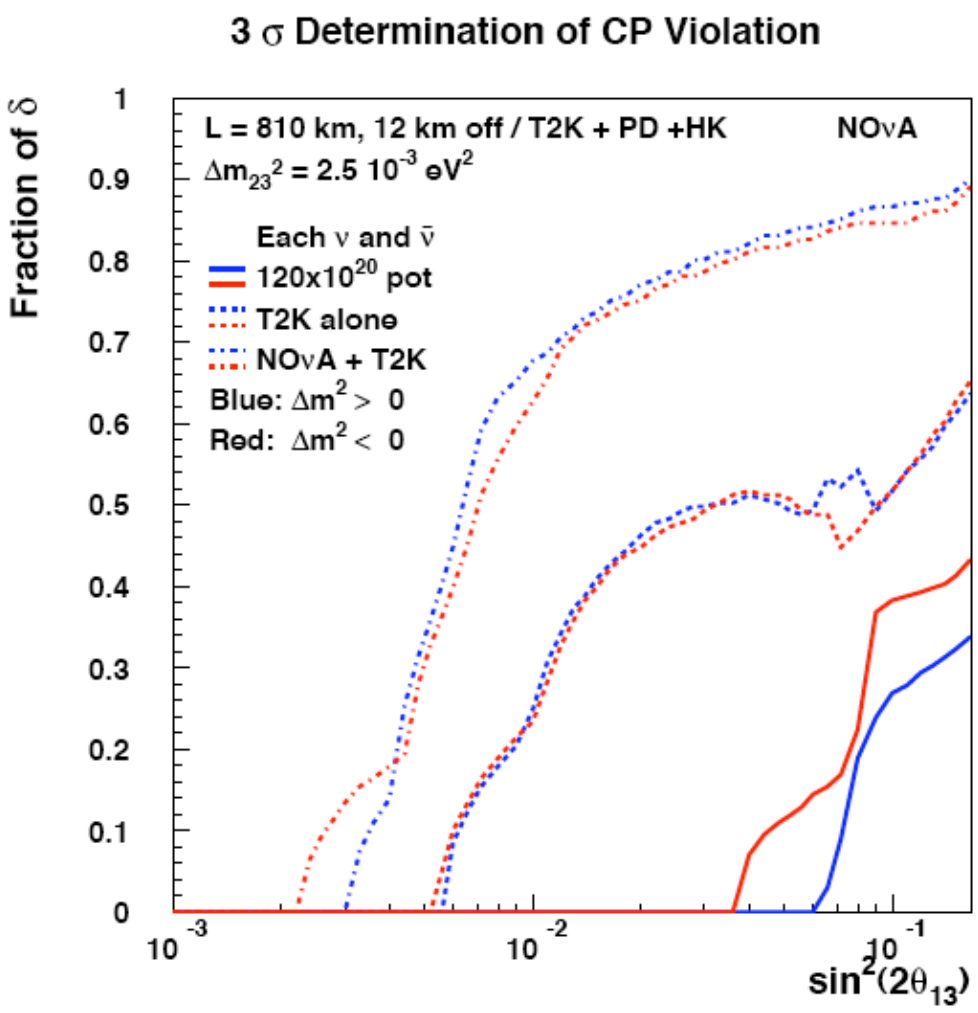
3σ Demonstration of CP Violation



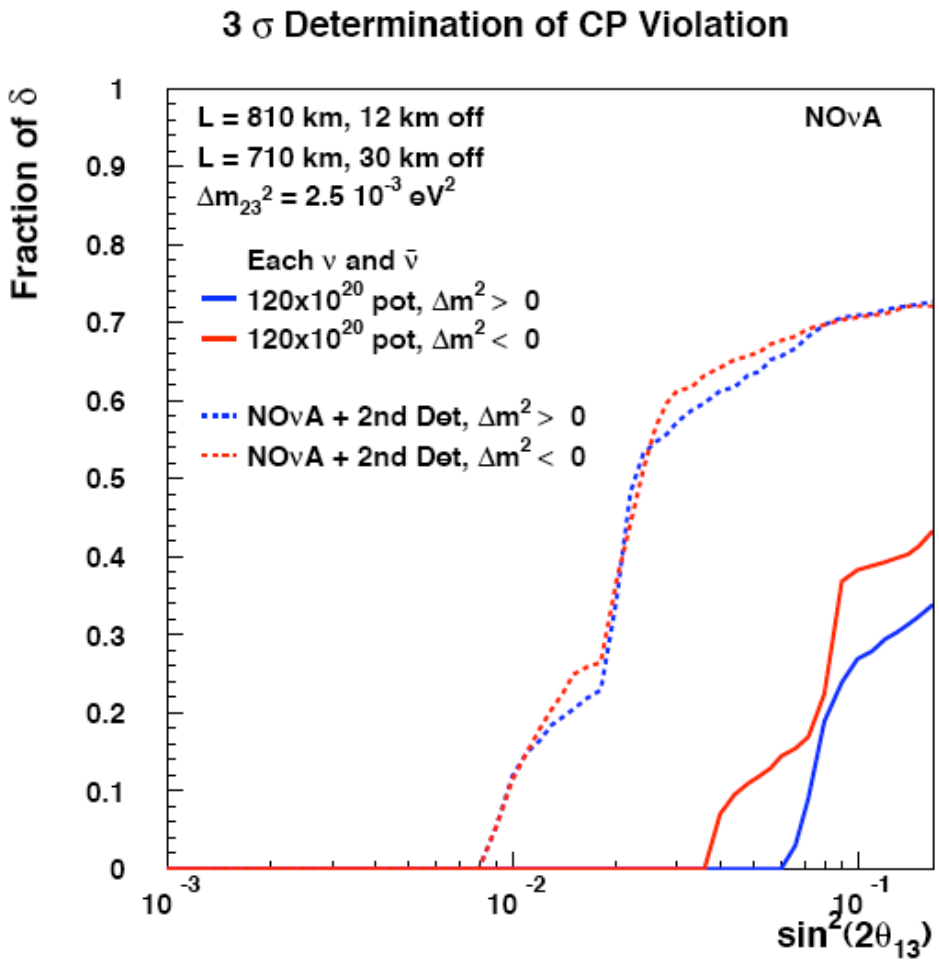
With proton drivers

(No 3σ CP effect in either T2K or NOνA without them.)

3 σ Demonstration of CP Violation

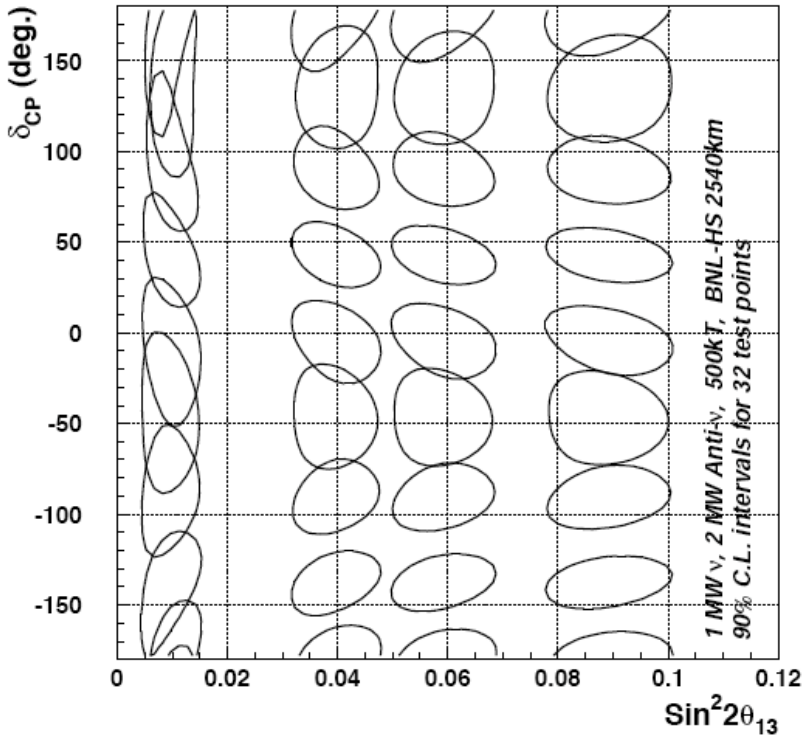


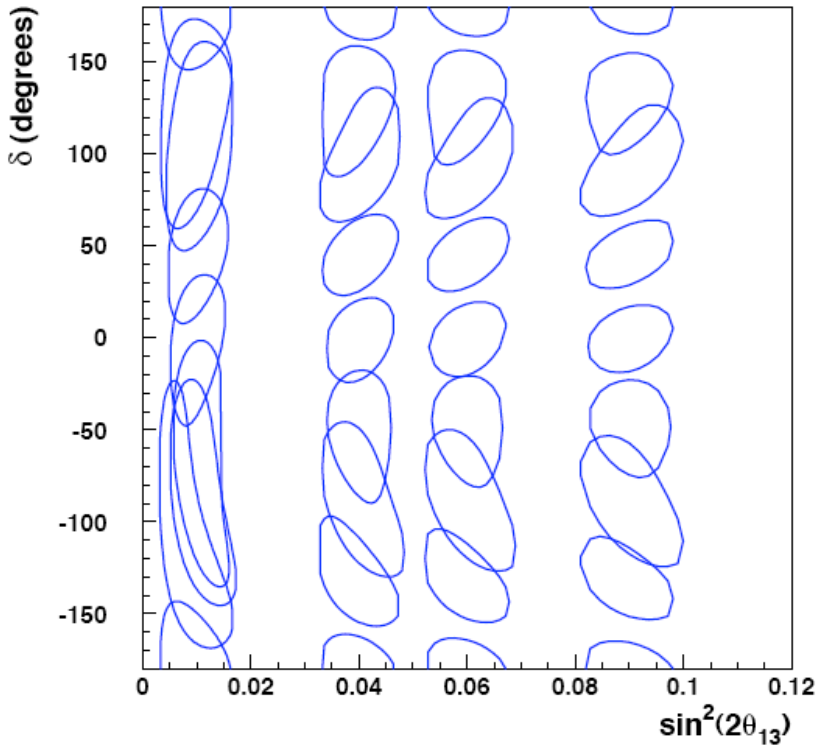
3 σ Demonstration of CP Violation



2nd Off-axis detector at the 2nd maximum

90% CL δ vs. $\sin^2(2\theta_{13})$ 5 yrs each ν and anti-ν





BNL Proposal **NOνA + PD + 2nd Det**

Conclusions to June PAC

- **NOνA provides a flexible approach to studying all of the parameters of neutrino oscillations**
  - **A long baseline approach is crucial in the context of the world program.**
  - **NOνA is the first stage of a flexible program where each stage can be planned according to what has been learned in previous stages.**
  - **The range of the NOνA program is comparable to that of other conventional approaches.**
  - **NOνA can be started now (same scale as NuMI/MINOS).**
  - **The approval road is long. We need PAC approval now to keep NOνA and the Fermilab neutrino program timely.**

PAC Response (1)

- **"To establish a compelling physics case, NOνA must meet the following criteria:**
  1. **Uniqueness. NOνA must have a unique physics capability not achieved by any other experiments worldwide.**
  2. **Competitiveness with T2K. NOνA must compete with T2K, the Japanese program discussed above, within a similar time frame.**
  3. **Competitiveness and/or complementarity with future experiments at reactors. NOνA must compete in sensitivity with reactor experiments, or provide information not obtainable by reactor experiments.**
  4. **Capability for evolution with a future neutrino program. NOνA must allow a natural progression to CP violation studies with a future proton driver with the currently proposed detector at the same location."**

PAC Response (2)

- The report then summarizes the physics case and concludes "The Committee finds the proposal meets the above four criteria if the detector can be built in a timely manner."
- "How soon must NOνA start taking data in order to be timely?… The Committee concludes that NOνA must start data-taking in the same time frame as T2K, and complete the far detector within four years to meet this criterion.… The Committee notes that the timely construction of NOνA is inconsistent with the present budget projection of the Laboratory."

PAC Response (3)

- "The Committee strongly endorses the physics case for the NOνA detector, and would like to see NOνA proceed on a fast track that maximizes its physics impact."
- "The Committee encourages the Laboratory to work together with the funding agencies to put the necessary funding profile in place for a construction start in FY 2007, or in FY 2008 at the latest."
- "The Committee strongly endorses the proposed R&D plan and urges the Laboratory to provide adequate support for timely completion of this program."

PAC Action

- **"While the Committee applauds [NOνA's] progress, it concludes that Stage I approval at this time is premature. The collaboration should first complete the following steps:"**
  - **Complete the critical R&D**
    - **Adequate signal from a full-length prototype**
    - **Cosmic ray background test**
    - **Engineering studies for TASD**
  - **Make a final technology choice**
  - **Update the proposal**

R&D Activities

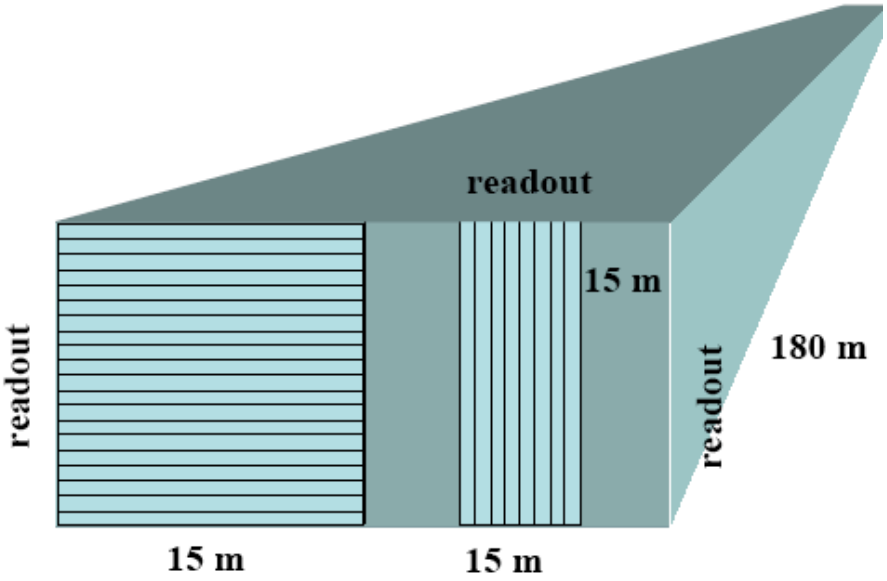
- Submitted a FY05 request to Fermilab for 513 k$
- Acquiring materials for the vertical-slice test
  - 3rd iteration on the PVC extrusion
  - Mechanical and electronics design underway
- Design of the cosmic ray test progressing
  - Plan to use MINOS spare scintillator modules and electronics
- Mechanical studies of TASD started
  - Half-scale prototype at Argonne using commercial extrusions (picture next slide)

Baseline Detector

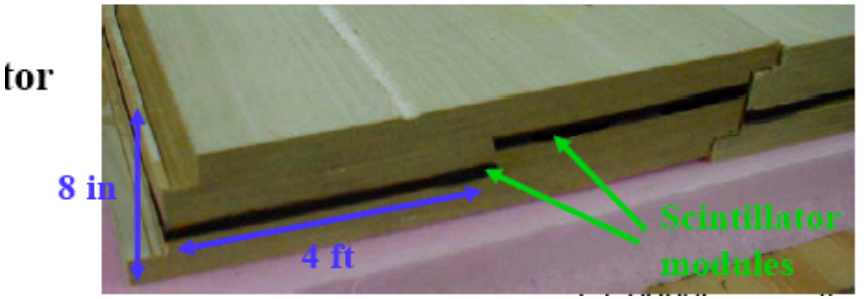
50 kT

Liquid Scintillator:
1.2 m x 3 cm x 14.4 m
30-cell PCV extrusions,
24 extrusions/plane,
750 planes
= 18,000 extrusions
= 540,000 channels
U-shaped WLS fiber into APD readout

Absorber:
20 cm particleboard/ plane (~1/3 X_o)



800 planes X, absorber, Y, absorber, … = detector

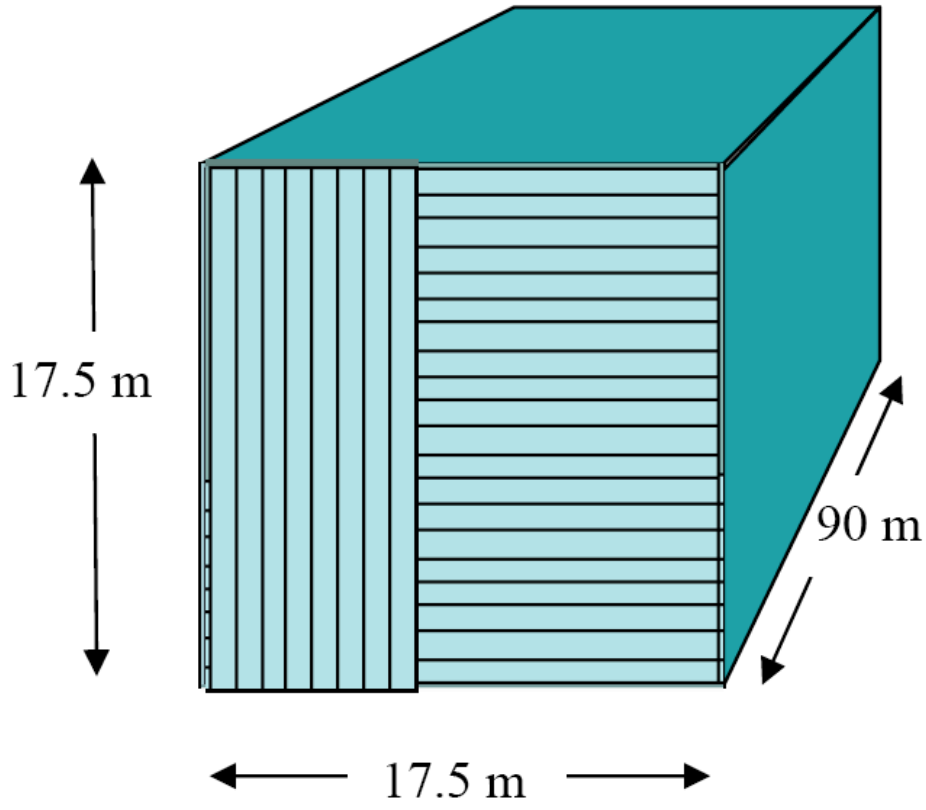


Alternative Under Study: Totally Active Scintillator Detector (TASD)

25 kT

Liquid Scintillator:
1.28 m x 4.9 cm x 17.5 m
32-cell PCV extrusions,
14 extrusions/plane,
1845 planes
= 25,830 extrusions
= 826,560 channels
U-shaped WLS fiber into APD readout

Absorber: None



Comparisons

	Baseline	TASD
Mass	50 kT	25 kT
Optimized ν_e efficiency	18%	32%
Optimized s/b	4.8	7.7
FoM	24.5	24
Cost	$147M	$159M

No obvious drawbacks to TASD so far.

Visit to the DoE

- On August 24, J. Cooper, D. Michael, H. Montgomery, S. Parke, S. Wojcicki, and I met with Robin Staffin, about 7 members of his staff, and Joe Dehmer for about 2 1/2 hours.
- I think we were successful in educating them on the physics case for NOνA and giving them a story they could sell in Washington. (Next talk)

Other Developments

- APS Study endorsement. (Talk after next)
- Linear Collider technology decision.
- Proton Driver workshop (starts Wednesday).
- Designation of a new Fermilab director.
- National Academy study.
- A neutrino subpanel?